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FORECASTING THE NUMBERS AND TYPES OF ENLISTED PERSONNEL IN THE UNITED STATES MARINE CORPS: AN INTERACTIVE COHORT MODEL

by

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In this report we develop a model to forecast the total enlisted Marine Corps strength at the end of each quarter for one or two years into the future. The method involves a simple cohort model. The model is programmed in APL with a number of features which allow the user to interact in the forecasting procedure. He can introduce further projected retention policy changes or changes in the recruit population which might affect future

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predictions.

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1. Introduction

In this report we develop a model to forecast the total enlisted Marine Corps strength at the end of each quarter for one or two years into the future. The method involves a simple cohort model similar to that described in Zacks and Haber [1975]. The model is programmed in APL with a number of features which allow the user to interact in the forecasting procedure. He can introduce further projected retention policy changes or changes in the recruit population which might affect future predictions.

In Section 2 we describe the cohort model and present the equations for forecasting. In Section 3 we discuss a number of ways of determining the parameters in the model from past data. In Section 4 we describe how steady state results can be obtained. In Section 5 we describe the use of the APL programs which comprise the model, and present illustrative examples. Detailed and documented APL functions are given in the appendix.

2. The Basic Model

It has been shown previously (see, for example, Zacks and Haber [1975] that retention behavior patterns of enlisted marines are reasonably consistent within certain subgroups of the total population. It has been found that the important characteristics to be used in forming the subgroups appear to be race, educational level, and length of first term enlistment (FTE) of new recruits. For race we take the groups Caucasian (C) and non-Caucasian (NC); for education we take the groups high school graduate (HS) and non-high school graduate (LHS); for FTE we have 2, 3 and 4 year enlistments. Thus all recruits and current marines can be uniquely placed into one of the 12 cohorts (groups) in Table 1.

Cohort No.	FTE	Education	Race
1	2	LHS	C
2	2	LHS	NC
3	2	HS	C
4	2	HS	NC
5	3	LHS	C
6	3	LHS	NC
7	3	HS	C
8	3	HS	NC
9	4	LHS	C
10	4	LHS	NC
11	4	HS	C
12	4	HS	NC

Table 1: The twelve cohorts of the enlisted Marine Corps personnel.

Let $S_i(t;u)$ be the "stock" of enlisted Marine Corps personnel in cohort type i at time t with length of service (LOS) equal to u (for a detailed descripton of cohort models the reader should see Grinold and Marshall [1977]). The time periods are taken to be quarters, and the phrase "at time t" means the last day of quarter t. For consistency the LOS is also measured in quarters. If a person enters the Marine Corps in quarter t and is counted as being present at time t, then we say he has LOS equal to 1. Thus, if he enters in t and is counted at time $t+k$, $k \geq 0$, then he has LOS equal to $k+1$. Table 2 gives the stocks at the end of March 1976 of marines who were listed as being still in their first term enlistment.

Let $q_i(u)$ be the fraction of those in cohort type i with LOS equal to u at some time t who will continue in service to time $t+1$ with LOS $u+1$. The $q_i(u)$ are commonly called "continuation rates." By using this notation we are assuming that they are independent of the actual time t. This assumption is modified later. Let $g_i(t)$ be the number of new recruits who enter in cohort type i in period t, and let m be the maximum number of periods a person can spend in the Marine Corps. The total stock $S(t+1)$ of marines at $(t+1)$ is given by

$$(1) \qquad S(t+1) = \sum_{i=1}^{12} \sum_{u=1}^{m} S_i(t+1;u) \ ,$$

where

$$(1.1) \quad S_i(t+1;1) = g_i(t+1)\ q_i(0)$$

$$(1.2) \quad S_i(t+1;u) = S_i(t;u-1)\ q_i(u-1), \quad u = 2,3,\ldots,m.$$

In order to use equation (1) to forecast end strength it is necessary to know (i) the cohort stocks $\{S_i(t;u)\}$ for all i and all u, (ii) the continuation rates $\{q_i(u)\}$ for all i and all u, and (iii) the future recruit inputs $\{g_i(t+1)\}$ for all i. It is the determination of these three sets of data to which we now turn.

The new recruit input in future years will be given to the model by the user and thus we can dispose of (iii). Table 2 shows the stocks of marines who are still in their first term enlistment at some given t for each cohort i, but only for $u = 1,2,\ldots,20$. Marines can reenlist and remain in service 30 years; thus m is $4 \times 30 = 120$. But as the LOS of a marine increases beyond his FTE period there is little distinction to be found among the 12 cohorts. These marines essentially form what is called the "career" force, and continuation in service of these people is governed by a different set of factors than those affecting first term marines. Thus, we modify equation (1) in the following way to reduce both the size of the model and the number of parameters to be estimated.

LOS	Cohort Number											
	1	2	3	4	5	6	7	8	9	10	11	12
1	3	0	3	2	1706	301	1424	422	2419	410	2982	588
2	5	4	14	2	931	134	1256	299	2635	497	3418	797
3	48	12	221	33	907	132	1683	387	2441	462	5563	1166
4	165	29	879	117	495	81	1041	236	1749	336	4276	907
5	527	92	806	137	928	211	645	147	3143	897	2563	582
6	543	154	804	202	672	210	495	187	2372	793	2013	503
7	845	235	1926	541	736	247	936	299	2180	697	3841	816
8	380	128	899	387	301	108	560	196	1107	356	2685	700
9	197	80	248	85	794	200	545	143	1981	583	1433	340
10	83	39	140	51	547	124	436	108	1487	435	1179	334
11	43	27	174	34	508	122	876	185	1688	387	2846	624
12	23	31	50	21	414	96	460	124	1721	400	1892	407
13	26	13	52	22	126	39	123	50	1502	394	1147	350
14	20	12	25	11	61	18	70	28	1187	360	1176	404
15	30	19	74	24	52	24	123	41	1282	354	2409	530
16	31	20	24	18	40	11	62	28	932	206	1562	281
17	22	7	17	9	26	6	25	11	325	70	285	86
18	14	4	7	3	19	8	14	4	150	17	186	44
19	6	5	14	5	11	0	33	10	119	17	279	61
20	4	1	6	4	10	2	19	3	101	32	157	28

Table 2: Stocks of enlisted Marines on 31 March 1976.

Let $c(t)$ be the total number of enlisted marines in service time t with 21 or more quarters of service. Thus

$$c(t) = \sum_{i=1}^{12} \sum_{u=21}^{m} S_i(t;u).$$

Now assume that $q_i(u) = q$ for all $u \geq 20$ and $i = 1,2,...,12$. Using (1.2) it is easy to show that

$$(2) \qquad c(t+1) = [c(t) + \sum_{i=1}^{12} S_i(t;20)]q \; .$$

Equations (1) and (2) are now combined to give the forecasting equation

$$(3) \qquad S(t+1) = \sum_{i=1}^{12} \sum_{u=1}^{20} S_i(t+1;u) + c(t+1)$$

where

$$(3.1) \quad S_i(t+1;1) = g_i(t+1)\; q_i(0)$$

$$(3.2) \quad S_i(t+1;u) = S_i(t;u-1)\; q_i(u-1),\; u = 2,3,\ldots,20$$

$$(3.3) \quad c(t+1) = [c(t) + \sum_{i=1}^{12} S_i(t;20)]q.$$

Equation (3) requires only 241 continuation rates compared to 1452 in (1). This gives a considerable saving in data, computation, and storage requirements. Figure 1 illustrates the flows assumed in (3).

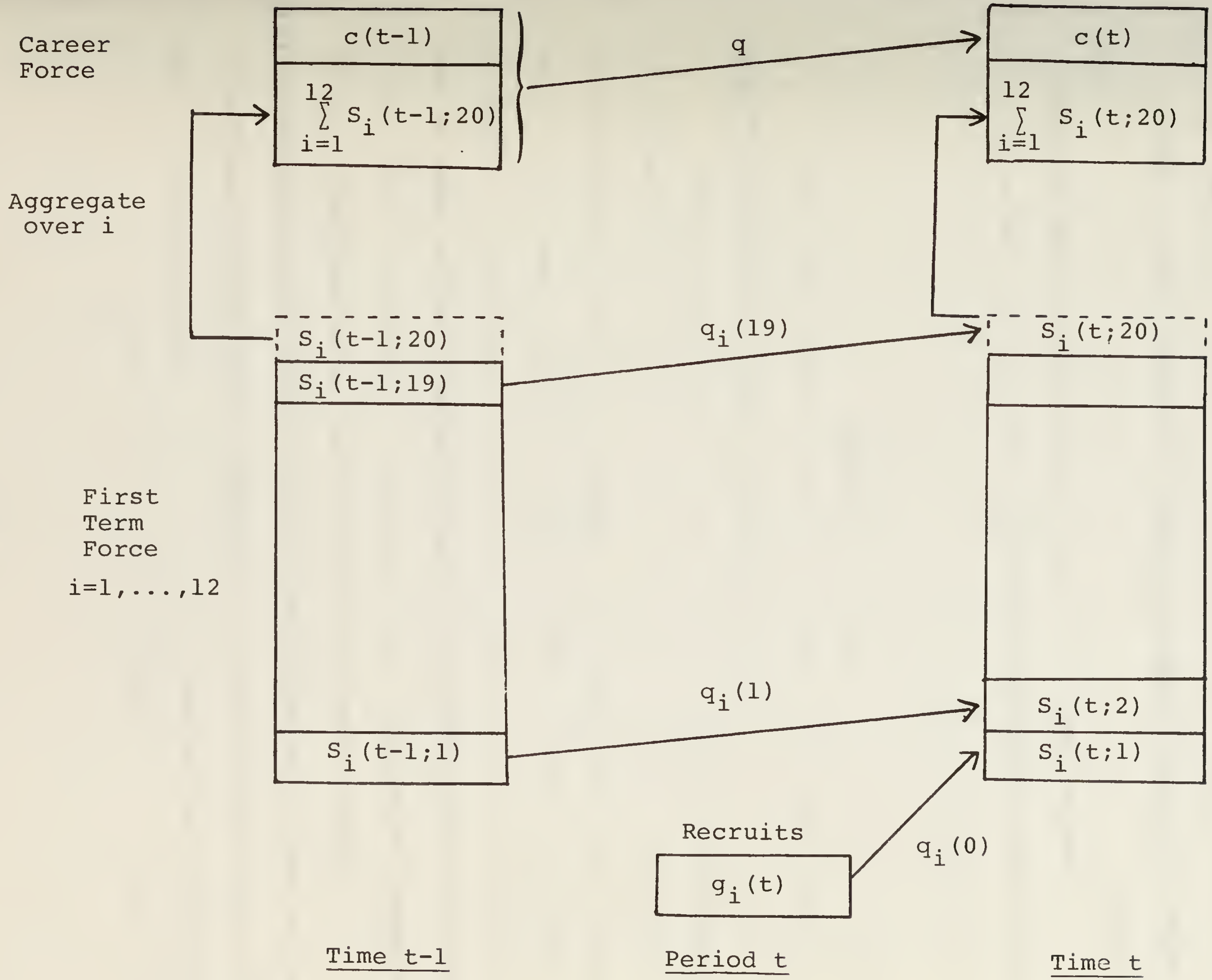

Figure 1: Illustration of flows in the forecasting Model

3. Continuation Rate Estimation

Before (3) can be used for forecasting we must obtain values of $q_i(u)$, $u = 0,1,\ldots,19$, $i = 1,2,\ldots,12$, and q. These values are determined from historical data on past stocks.

Assume that $t = 0$ is the most recent time for which stocks are available. By using these and the stocks at $t = -1$, let

(4) $$q_i(u) = \frac{S_i(0;u+1)}{S_i(-1;u)},$$

$$u = 0,1,\ldots,19; \qquad i = 1,2,\ldots,12,$$

and

(5) $$q = \frac{c(0)}{c(-1) + \sum_{i=1}^{12} S_i(-1;20)}$$

Thus all the parameters can be estimated from the data of two consecutive periods.

If data from more than two periods is available we can use it to obtain smoother estimates, ones less susceptible to random fluctuations in the stocks. Assume that data is available for periods $0,-1,-2,\ldots,-k$. Then we modify (4) and (5) to be

(6) $$q_i(u) = \frac{\sum_{j=0}^{-(k-1)} S_i(j;u+1)}{\sum_{j=-1}^{-k} S_i(j;u)}$$

$$u = 0,1,\ldots,19; \quad i = 1,2,\ldots,12$$

and

(7) $$q = \frac{\sum_{j=0}^{-(k-1)} c(j)}{\sum_{j=-1}^{-k} \{c(j) + \sum_{i=1}^{12} S_i(j;20)\}}$$

The values obtained using (6) and (7) for any given k are said to be determined using rate method k.

Recruit attrition in the first six months of service is measured by $(1-q_i(0))$ and $(1-q_i(1))$, and is considered controllable by the Marine Corps. Estimates from past data have little meaning. In the interactive APL model described in detail in Section 4, recruit attrition is entered directly by the user at the computer terminal. The six month attrition of LHS and HS recruits is normally about 20% and 10% respectively. The conversion of these into $q_i(0)$ and $q_i(1)$ is illustrated for some cohort i if a six month rate r is entered. They are calculated by

(8) $$q_i(0) = q_i(1) = \sqrt{1 - (r/100)}\ ,$$

which spreads attrition evenly over the six month period.

Table 3 gives the continuation rates $q_i(u)$ obtained using rate method 2 with $t = 0$ equal to 3-31-1976, and recruit attrition for LHS and HS equal to 15% and 12%, respectively. The value obtained for q was 0.980.

The reader will notice that some of the $q_i(u)$ in Table 3 exceed 1.0. Although this could be in part due to errors in the data base, it is also in part due to the return from unauthorized absences. Note that this phenomenon occurs most frequently when the LOS is 2 and 3. This is a period immediately following the end of basic training, when many Marines return after being AWOL. Thus they are counted in the numerator of (4) or (6) but are not present to be counted in the denominator.

LOS	Cohort Number 1	2	3	4	5	6	7	8	9	10	11	12
0	0.922	0.922	0.938	0.938	0.922	0.922	0.938	0.938	0.922	0.922	0.938	0.938
1	0.922	0.922	0.938	0.938	0.922	0.922	0.938	0.938	0.922	0.922	0.938	0.938
2	1.251	1.583	0.997	1.070	1.011	1.098	0.986	1.038	0.995	1.032	0.983	1.012
3	0.948	1.032	0.996	0.985	0.973	0.990	0.976	0.985	0.956	0.984	0.986	0.991
4	0.943	0.945	0.996	1.003	0.932	0.915	0.977	0.955	0.927	0.938	0.979	0.965
5	0.927	0.906	0.992	0.977	0.913	0.893	0.994	0.962	0.925	0.908	0.985	0.996
6	0.952	0.946	0.984	0.968	0.914	0.940	0.986	0.951	0.932	0.886	0.981	0.967
7	0.841	0.815	0.912	0.912	0.936	0.855	0.971	0.963	0.926	0.916	0.981	0.971
8	0.260	0.321	0.354	0.356	0.914	0.865	0.981	0.992	0.911	0.883	0.988	0.978
9	0.563	0.516	0.715	0.610	0.906	0.908	0.963	0.978	0.909	0.921	0.968	0.948
10	0.464	0.652	0.800	0.634	0.930	0.883	0.954	0.957	0.903	0.855	0.976	0.942
11	0.626	0.937	0.783	0.821	0.867	0.860	0.875	0.873	0.900	0.886	0.979	0.955
12	0.674	0.639	0.494	0.667	0.250	0.312	0.253	0.342	0.918	0.875	0.985	0.956
13	0.712	0.649	0.876	0.846	0.517	0.576	0.626	0.687	0.926	0.909	0.971	0.970
14	0.892	0.703	0.840	0.758	0.636	0.697	0.786	0.763	0.935	0.918	0.971	0.940
15	0.800	0.775	0.810	0.805	0.745	0.611	0.835	0.800	0.877	0.869	0.906	0.930
16	0.923	0.722	0.659	0.714	0.763	0.714	0.867	0.727	0.286	0.323	0.283	0.464
17	0.667	0.643	0.875	0.438	0.914	0.909	1.000	0.824	0.607	0.621	0.645	0.742
18	0.700	1.000	0.885	0.889	0.929	0.600	1.000	1.000	0.762	0.762	0.815	0.773
19	0.600	0.833	0.688	0.909	0.914	1.000	1.032	0.733	0.840	0.927	0.917	0.908

Table 3: Continuation rates using Method 2

4. Steady State Results

The model summarized mathematically in equation (3) is used for short-term forecasting (1 or 2 years) under a given recruitment policy. The basic model can also be used to show the long-run, or steady-state, effects of a fixed recruitment policy. Although it is unlikely that the system parameters will remain constant over many periods or that recruitment policies will remain unchanged, the long run behavior of the system under a given policy is often useful in showing trends. These trends can act as warning signals of future problems.

Let L_i be the random lifetime of an individual of cohort type i. Let $Q_i(\ell) = P[L_i > \ell]$; then

$$Q_i(\ell) = \prod_{u=0}^{\ell} q_i(u) , \qquad \ell = 0,1,2,\ldots,m . \tag{9}$$

Now let λ_i be the average time spent in the Marine Corps of an individual in cohort type i, and let g_i be the fixed quarterly recruit input into this cohort. The stocks $S(t)$ converge to a constant stock level S, where

$$S = \sum_{i=1}^{12} \lambda_i g_i \tag{10}$$

and

$$\lambda_i = \sum_{\ell=0}^{m} Q_i(\ell) . \tag{11}$$

Recall that we assumed that for $u \geq 20$ and all $i = 1,2,\ldots,12$, $q_i(u) = q$, a constant. Recall also that m is 120 so that $q^{m-19} = q^{99}$ is negligible for values of q of interest. From (9) we have

$$Q_i(\ell) = \prod_{u=0}^{\ell} q_i(u) , \qquad \ell = 0,1,\ldots,19$$

$$= Q_i(19)\, q^{\ell-19} , \qquad \ell \geq 19$$

Using these with (11) and (10) gives for the steady state stock level

$$S = \sum_{i=1}^{12} \left[\sum_{\ell=0}^{18} Q_i(\ell) + \frac{Q_i(19)}{1-q} \right] g_i \tag{12}$$

To illustrate the use of (12), Table 4 gives the life distributions $Q_i(u)$ for the continuation rates in Table 3 for $\ell \leq 19$. Using the constant recruitment policy shown in Table 5 and $q = 0.980$, the steady state stocks will become 163,149.

In addition to calculating S, many more steady state calculations of interest can be made. For example, the steady state fraction with less than high school education is given by

$$(\lambda_1 g_1 + \lambda_2 g_2 + \lambda_5 g_5 + \lambda_6 g_6 + \lambda_9 g_9 + \lambda_{10} g_{10})/S .$$

LOS	Cohort Number 1	2	3	4	5	6	7	8	9	10	11	12
0	0.922	0.922	0.938	0.938	0.922	0.922	0.938	0.938	0.922	0.922	0.938	0.938
1	0.850	0.850	0.880	0.880	0.850	0.850	0.880	0.880	0.850	0.850	0.880	0.880
2	1.064	1.346	0.878	0.942	0.859	0.933	0.868	0.914	0.846	0.878	0.865	0.890
3	1.008	1.389	0.874	0.927	0.836	0.924	0.847	0.900	0.808	0.864	0.853	0.883
4	0.951	1.312	0.870	0.930	0.779	0.846	0.828	0.859	0.749	0.810	0.835	0.851
5	0.881	1.189	0.864	0.908	0.711	0.756	0.823	0.827	0.693	0.736	0.822	0.848
6	0.839	1.125	0.850	0.880	0.649	0.710	0.811	0.786	0.646	0.653	0.807	0.820
7	0.705	0.916	0.775	0.802	0.608	0.607	0.787	0.757	0.598	0.598	0.792	0.796
8	0.183	0.294	0.274	0.285	0.556	0.526	0.773	0.751	0.545	0.528	0.782	0.779
9	0.103	0.152	0.196	0.174	0.503	0.477	0.744	0.734	0.495	0.486	0.757	0.738
10	0.048	0.099	0.157	0.110	0.468	0.421	0.710	0.703	0.447	0.416	0.739	0.695
11	0.030	0.093	0.123	0.091	0.406	0.362	0.621	0.614	0.402	0.368	0.723	0.664
12	0.020	0.059	0.061	0.060	0.102	0.113	0.157	0.210	0.369	0.322	0.713	0.635
13	0.014	0.038	0.053	0.051	0.053	0.065	0.098	0.144	0.342	0.293	0.692	0.616
14	0.013	0.027	0.045	0.039	0.033	0.045	0.077	0.110	0.320	0.269	0.672	0.579
15	0.010	0.021	0.036	0.031	0.025	0.028	0.065	0.088	0.280	0.234	0.609	0.538
16	0.009	0.015	0.024	0.022	0.019	0.020	0.056	0.064	0.080	0.075	0.172	0.250
17	0.006	0.010	0.021	0.010	0.017	0.018	0.056	0.053	0.049	0.047	0.111	0.185
18	0.004	0.010	0.018	0.009	0.016	0.011	0.056	0.053	0.037	0.036	0.091	0.143
19	0.003	0.008	0.013	0.008	0.015	0.011	0.058	0.039	0.031	0.033	0.083	0.130

Table 4: Cumulative tail distributions of length of service

Cohort No.	Number of Recruits
1	
2	
3	
4	
5	1428
6	252
7	2142
8	378
9	2652
10	468
11	3978
12	702
TOTAL	12,000

Table 5: Quarterly input of recruits into each cohort

Similarly, the steady state fraction of non-Caucasions in the force is given by

$$(\lambda_2 g_2 + \lambda_4 g_4 + \lambda_6 g_6 + \lambda_8 g_8 + \lambda_{10} g_{10} + \lambda_{12} g_{12})/S \ .$$

5. Interactive Program Illustration

In this section we describe the use of a set of interactive APL functions for both data input and enlisted end-strength forecasting. These functions are available in Scientific Time Sharing's *APL+* system in a workspace called *ENLISTED*. Listings and documentation of the functions are given in the Appendix.

a) Data Input and Storage

There are 3 functions used to input, display and correct the stocks $\{S_i(t;u)\}$ for any given time period t. These are

(i) *INPUTSTK*

(ii) *DISPLAYSTK*

(iii) *CORRECTSTK*

INPUTSTK is a function that requires no arguments. It asks the user for the time period t, and for each cohort $i=1,2,\ldots 12$ it asks for the 20 numbers $\{S_i(t;u),\ u=1,2,\ldots,20.\}$. After these are entered it asks for the remainder of the force, $c(t)$. A sample use of *INPUTSTK* is shown in Figure 2. The data is stored in a file called '4894733 *STOCKS*'; details of the file format can be found in the Appendix.

DISPLAYSTK is a monadic function which takes as its right hand argument a 2 element vector of month and year, and displays the stocks for that time period with suitable headings. Table 6 demonstrates the use of *DISPLAYSTK* for data on 31 March 1976.

CORRECTSTK is a monadic function which takes as its right hand argument a 2 element vector of month and year. After using *DISPLAYSTK* to observe the stocks on file, *CORRECTSTK* can be used to make any necessary corrections. A sample use of *CORRECTSTK*

```
      INPUTSTK
 TIME PERIOD? EG. 9 75 FOR END OF MONTH 9 OF 1975
⎕:
      3 76
2 LHS  W
LOS    1     2     3     4     5     6     7     8     9    10    11    12    13    14    15    16    17    18    19    20
⎕:
      3     5    48   165   527   543 845   380   197    83    43    23    26    20    30    31    22    14  6      4
2 LHS NW
LOS    1     2     3     4     5     6     7     8     9    10    11    12    13    14    15    16    17    18    19    20
⎕:
      0     4    12    29    92   154   235   128  80    39    27    31    13    12    19    20     7     4     5     1
2  HS  W
LOS    1     2     3     4     5     6     7     8     9    10    11    12    13    14    15    16    17    18    19    20
⎕:
```

Figure 2: Illustration of *INPUTSTK*

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		LOS																			
NO.	*TYPE*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	2 *LHS W*	3	5	48	165	527	543	845	380	197	83	43	23	26	20	30	31	22	14	6	4
2	2 *LHS NW*		4	12	29	92	154	235	128	80	39	27	31	13	17	19	20	7	4	5	1
3	2 *HS W*	3	14	221	879	806	804	1926	899	248	140	174	50	52	25	74	24	17	7	14	6
4	2 *HS NW*	2	2	33	117	137	202	541	387	85	51	34	21	22	11	24	18	9	3	5	4
5	3 *LHS W*	1706	931	907	495	928	672	736	301	794	547	508	414	126	61	52	40	26	19	11	10
6	3 *LHS NW*	301	134	132	81	211	210	247	108	200	124	122	96	39	18	24	11	6	8		2
7	3 *HS W*	1424	1256	1683	1041	645	495	936	560	545	436	876	460	123	70	123	62	25	14	33	19
8	3 *HS NW*	422	299	387	236	147	187	299	196	143	108	185	124	50	28	41	28	11	4	10	3
9	4 *LHS W*	2419	2635	2441	1749	3143	2372	2180	1107	1981	1487	1688	1721	1502	1187	1282	932	325	150	119	101
10	4 *LHS NW*	410	497	462	336	897	793	697	356	583	435	387	400	394	360	354	206	70	17	17	32
11	4 *HS W*	2982	3418	5563	4276	2563	2013	3841	2685	1433	1179	2846	1892	1147	1176	2409	1562	285	186	279	157
12	4 *HS NW*	588	797	1166	907	582	503	816	700	340	334	624	407	350	404	530	281	86	44	61	28

NO. WITH LOS>20:- 48049

TOTAL END STR:- 174823

Table 6: Illustration of *DISPLAYSTK*

is shown in Figure 3.

b) <u>Endstrength Forecasts</u>

The function *ENDSTR* is used to calculate end-strengths for given recruitment policies using equation (3). It requires no arguments, but interactively asks the user for the following data:

(i) Number of periods to project (call this n)

(ii) Base Period

After these it asks for the following data for recruits for each of the next n periods:

(iii) Percent Caucasian

(iv) Percent 3-Year Enlistments (it is currently assumed that there are no 2-Year Enlistments)

(v) Percent of high school graduates in caucasian recruits

(vi) Percent of high school graduates in non-caucasian recruits

(vii) Total recruits in each period

(viii) First 6-month attrition percent for high school graduates

(ix) First 6-month attrition percent for those without high school education

The answers to (iii) through (ix) are used to spread the recruits in each period over the 12 cohorts. The next input required is

(x) Continuation rate method (see section 3)

(xi) Does the user wish to change the continuation rates.

If the answer to (xi) is yes, the user is asked for

(xi-a) High school graduate factor

(xi-b) Non high school graduate factor

```
      CORRECTSTK 3 76
TO END, ENTER COHORT NO. 0.  TO CHANGE >20, USE COHORT NO. 1, LOS 21
 COHORT NO.?
⎕:
      12
LOS?
⎕:
      6
CURRENT:-553
NEW?
⎕:
      503
 COHORT NO.?
⎕:
      1
LOS?
⎕:
      21
CURRENT:-48152
NEW?
⎕:
      48049
 COHORT NO.?
⎕:
      0
```

Figure 3. Demonstration of *CORRECTSTK*

These factors are used to multiply all the continuation rates for the given cohort type. This approach is used rather than asking the user for changes in each of the 241 rates.

After answers have been given to questions (i) through (xi) the end-strengths are calculated using equation (3) and stored on a temporary file. When the calculations are completed a report is printed showing the recruit policies used and the end-strengths obtained. Following this printed report the user is asked if he wishes to continue. If the answer is yes, the user can then pick a subset or all of the questions (i) through (xi) to enter different data and rerun the model. An example run follows in Figure 4.

```
      ENDSTR
1.  NO. PERIODS TO PROJECT?
⎕:
      4
2.    BASE PERIOD? EG 12 75
⎕:
      3 76
3. RECRUIT PERCENT WHITE?
      1      2      3      4
⎕:
      85     83     84     85
4. 3 YR SPLIT?
      1      2      3      4
⎕:
      35     37     33     34
5. W HS GRAD PERCENT?
      1      2      3      4
⎕:
      58     55     62     60
6.  NW HS GRAD PERCENT?
      1      2      3      4
⎕:
      60     60     58     58
7.    TOTAL RECRUITS EACH OF NEXT 4 QUARTERS?
      1      2      3      4
⎕:
      12000 11200  11500 11500
8.HS  6 MONTH PERCENT ATTR?
      1      2      3      4
⎕:
      12     12     10     10
9.  LHS 6 MONTH PERCENT ATTRITION?
      1      2      3      4
⎕:
      20     18     17     15
```

Figure 4. Sample Use of *ENDSTR*

```
10.   RATE METHOD? 1-3
⎕:
      2
CHANGE RATES? NO


       USMC FORECASTED ENDSTRENGTHS        9 MARCH 1977


BASE PERIOD: 3 76
RATE METHOD: 2
HS FACTOR: 1
LHS FACTOR: 1

    PERIOD    PERC W  PERC 3YR    W-HS    NW-HS    HS-RA    LHS-RA  RECRUITS   END STR TOTAL ATTR
                                                                              174823
         1        85        35      58       60       12        20     12000   173669     13154
         2        83        37      55       60       12        18     11200   170361     14508
         3        84        33      62       58       10        17     11500   169806     12055
         4        85        34      60       58       10        15     11500   169490     11816
STDY. STATE                                                                   158906
CONTINUE? YES
 QUEST NOS.?
⎕:
      10 7
10.   RATE METHOD? 1-3
⎕:
      1
7.    TOTAL RECRUITS EACH OF NEXT 4 QUARTERS?
      1      2      3      4
⎕:
      4⍴12000
```

Sample Use of *ENDSTR* (Continued)

```
CHANGE RATES? YES
HS GRAD FACTOR?
⎕:
      1.01
LHS FACTOR?
⎕:
      1.02


      USMC FORECASTED ENDSTRENGTHS        9 MARCH 1977


BASE PERIOD: 3 76
RATE METHOD: 1
HS FACTOR: 1.01
LHS FACTOR: 1.02

    PERIOD    PERC W  PERC 3YR     W-HS     NW-HS     HS-RA     LHS-RA  RECRUITS   END STR TOTAL ATTR
                                                                                  174823
         1       85        35       58        60        12        20     12000    175245      11578
         2       83        37       55        60        12        18     12000    173892      13353
         3       84        33       62        58        10        17     12000    174976      10916
         4       85        34       60        58        10        15     12000    176154      10822
STDY. STATE                                                                       198347
CONTINUE? NO
```

Sample Use of *ENDSTR* (Continued)

References

Zacks, S. and Haber, S. E., "A Procedure for Forecasting the Size of a Force Subject to Random Withdrawal," Report No. T-312, Institute of Man. Sci., George Washington University, Washington, D.C. 20037 (1975).

Grinold, R. C. and Marshall, K. T., "Manpower Planning Models," North-Holland Press, New York (1977).

Appendix

1. Files

The forecast model requires 2 files for execution. The file '4894733 *STOCKS*' contains historical data on enlisted Marines (for details of file creation, manipulation and security, see the booklet on the *APL+* file subsystem from Scientific Time Share Corp.) component 1 of this file contains data for 30 June 1975, component 2 the data for 30 September 1975, etc. The format of the data is shown in Table 6 of the main report.

The file '4894733 *FORECAST*' is used to store the forecasted force and attrition whenever the function *ENDSTR* is used. It is used to facilitate the printing of various statistics on the forecasted force and attrition. Its use will greatly simplify satisfying any future request and allow the user to display many kinds of data without re-running *ENDSTR*.

The format of each component of this file is shown in Table 7. Each component is a 24 x 21 matrix. Rows 1-12 of component 1 give the base period stocks as in Table 6 with column 21 having the stock with LOS > 20 in the top row, followed by 11 zeros. Rows 13-24 of component 1 contain zeros. Component i ($i \geq 2$) contains the forecasted stocks and attrition for (i-1) periods after the base period. Rows 1-12 contain the forecasted stocks in the same format as component 1. Rows 13-24 contain the forecasted attrition from each cohort-LOS cell in the given period.

2. Functions

The use of the main functions is discussed in section 5 of the main report. This appendix contains detailed listings of the functions.

	Columns 1-20	Column 21
Rows 1-12	Component i: Forecasted Stocks (i-1) periods after base period (Base period stocks if i = 1)	Stocks with LOS > 20 0 ⋮ 0
Rows 13-24	Component i: Forecasted attrition (i-1) periods after base period (All zeros if i = 1)	Attrition with LOS > 20 0 ⋮ 0

Table 7: Format of a component in file '4894433 *FORECAST*'

```
      ∇INPUTSTK[⎕]∇
    ∇ INPUTSTK;I;T;CN;M;J;CV;V;X
[1]    ⎕FUNTIE ⎕FNUMS ◇ '4894733 STOCKS' ⎕FSTIE 1
[2]   L1:' TIME PERIOD? EG. 9 75 FOR END OF MONTH 9 OF 1975'
[3]    →(2=ρT←,⎕)ρL6 ◇ 'NEED 2 NOS.' ◇ →L1
[4]   L6:→(0=1|X←T[1]÷3)ρL2 ◇ 'MONTH MUST BE 3 6 9 OR 12' ◇ →L1
[5]   L2:CN←¯1+X+4×T[2]-75 ◇ M← 12 20 ρ0 ◇ I←1
[6]   L3:TTLEM[I;] ◇ J←0
[7]   L4:'LOS',,'I5' ⎕FMT⍳20 ◇ →(20=ρV←,⎕)ρL5 ◇ 'NEED 20 NOS.' ◇ →L4
[8]   L5:M[I;]←V
[9]    →(12≥I←I+1)ρL3 ◇ 'REMAINDER OF FORCE'
[10]  L7:→(1=ρY←,⎕)ρL8 ◇ 'ONE NUMBER ONLY' ◇ →L7
[11]  L8:(M←M,12↑Y) ⎕FREPLACE 1,CN
[12]   'TOTAL END STRENGTH:-';+/+/M
    ∇
      ∇DISPLAYSTK[⎕]∇
    ∇ DISPLAYSTK MY;M
[1]   ⍝TO DISPLAY STKS FOR PERIOD MY (MNTH,YR)
[2]    ⎕FUNTIE ⎕FNUMS ◇ '4894733 STOCKS' ⎕FSTIE 1
[3]    (50ρ' '),'LOS'
[4]    'NO.   TYPE   ',(,'I5' ⎕FMT⍳20)
[5]    ((12ρ3)⌽'I5' ⎕FMT⍳12),TTLEM,'BI5' ⎕FMT 0 ¯1 ↓M←⎕FREAD 1,¯1+(MY[1]÷3)+4×MY[2]-75
[6]    LF ◇ 'NO. WITH LOS>20:- ';M[1;21] ◇ LF ◇ 'TOTAL END STR:- ';+/+/M
    ∇
      ∇CORRECTSTK[⎕]∇
    ∇ CORRECTSTK MY;CN;I;J;M
[1]   ⍝TO CORRECT DATA IN STOCKS FOR TIME MY
[2]    ⎕FUNTIE ⎕FNUMS ◇ '4894733 STOCKS' ⎕FSTIE 1
[3]    M←⎕FREAD 1,CN←¯1+(MY[1]÷3)+4×MY[2]-75
[4]    'TO END, ENTER COHORT NO. 0.  TO CHANGE >20, USE COHORT NO. 1, LOS 21'
[5]   L1:' COHORT NO.?' ◇ →(0=I←⎕)ρL2
[6]    'LOS?' ◇ J←⎕
[7]    'CURRENT:-';M[I;J] ◇ 'NEW?' ◇ M[I;J]←⎕ ◇ →L1
[8]   L2:M ⎕FREPLACE 1,CN
    ∇
```

```
      ∇ENDSTR[⎕]∇
    ∇ ENDSTR;BPI;NQ;QI;QN;PT;W;NW;PRMT;Y4;Y3;WG;NWG;HSA;LHSA;CV;RV;HSF;LHSF;T;N
[1]   ⍝TIE FILES AND SET UP
[2]    ⎕FUNTIE ⎕FNUMS ◇ '4894733 STOCKS' ⎕FSTIE 1 ◇ '4894733 FORECAST' ⎕FSTIE 2 ◇ ⎕FDROP 2,-/2↑⎕FSIZE 2
[3]   ⍝SET QUESTION VECTOR
[4]    NQ←⍴QI←QN←L9,L1,L2,L3,L4,L10,L5,L6,L11,L7 ◇ PT←0 ◇ →LPT
[5]   ⍝RECRUIT DATA INPUT
[6]   L9:(LIT QN⍳L9),'. ',' NO. PERIODS TO PROJECT?' ◇ NP←⎕ ◇ →LPT
[7]   L1:(LIT QN⍳L1),'.     BASE PERIOD? EG 12 75' ◇ →(2=⍴BP←⎕)⍴LBP ◇ EM ◇ →L1
[8]   LBP:BPI←¯1+(BP[1]÷3)+4×BP[2]-75 ◇ →LPT
[9]   L2:(LIT QN⍳L2),'. RECRUIT PERCENT WHITE?' ◇ ⍞←PRMT←,'I7' ⎕FMT⍳NP ◇ →(NP≠⍴NW←1-W←0.01×,⎕)⍴L2E ◇ →LPT
[10]  L2E:EM ◇ →L2
[11]  L3:(LIT QN⍳L3),'. 3 YR SPLIT?' ◇ PRMT ◇ →(NP≠⍴Y4←1-Y3←0.01×,⎕)⍴L3E ◇ →LPT
[12]  L3E:EM ◇ →L3
[13]  L4:(LIT QN⍳L4),'. W HS GRAD PERCENT?' ◇ PRMT ◇ →(NP≠⍴WG←0.01×,⎕)⍴L4E ◇ →LPT
[14]  L4E:EM ◇ →L4
[15]  L10:(LIT QN⍳L10),'.  NW HS GRAD PERCENT?' ◇ PRMT ◇ →(NP≠⍴NWG←0.01×,⎕)⍴L10E ◇ →LPT
[16]  L10E:EM ◇ →L10
[17]  L5:(LIT QN⍳L5),'.    TOTAL RECRUITS EACH OF NEXT ',(LIT NP),' QUARTERS?' ◇ PRMT
[18]   →(NP=⍴T←,⎕)⍴LPT ◇ EM ◇ →L5
[19]   ' RECRUIT ATTRITION'
[20]  L6:(LIT QN⍳L6),'.HS  6 MONTH PERCENT ATTR?' ◇ PRMT ◇ →(NP≠⍴HSA←0.01×,⎕)⍴L6E ◇ →LPT
[21]  L6E:EM ◇ →L6
[22]  L11:(LIT QN⍳L11),'.  LHS 6 MONTH PERCENT ATTRITION?' ◇ PRMT ◇ →(NP≠⍴LHSA←0.01×,⎕)⍴L11E ◇ →LPT
[23]  L11E:EM ◇ →L11
[24]  L7:(LIT QN⍳L7),'.   RATE METHOD? 1-';BPI-1 ◇ N←⎕ ◇ →LPT
[25]  ⍝CALCULATE CONT. RATES
[26]  LCALC:RA←(12,NP)⍴LHSA,LHSA,HSA,HSA ◇ CR←RATE N ◇ HSF←LHSF←1
[27]   →(~AYN 'CHANGE RATES?')⍴LC ◇ 'HS GRAD FACTOR?' ◇ HSF←⎕ ◇ 'LHS FACTOR?' ◇ LHSF←⎕
[28]   CR[RV;CV]←HSF×CR[RV← 3 4 7 8 11 12 ;CV←⍳18] ◇ CR[¯2+RV;CV]←LHSF×CR[¯2+RV;CV]
[29]  ⍝SPREAD RECRUITS
[30]  LC:REC←RECRUITS T
[31]  ⍝AGE FORCE NP PERIODS AND STORE IN FILE FORECAST
[32]   ⎕FDROP 2,-/2↑⎕FSIZE 2 ◇ ((⎕FREAD 1,BPI),[1] 12 21 ⍴0) ⎕FAPPEND 2 ◇ AGE NP
[33]  ⍝PRINT OUTPUT REPORT
[34]   PRINTREPORT
[35]   →(AYN 'CONTINUE?')⍴LCONT ◇ →0
[36]  LCONT:' QUEST NOS.?'
[37]   NQ←⍴QI←,QN[⎕] ◇ PT←1 ◇ →QI[PT]
[38]  LPT:→(NQ<PT←PT+1)⍴LCALC ◇ →QI[PT]
    ∇
```

```
      ∇AGE[⎕]∇
    ∇ AGE N;I;M;W;A
[1]   ⍝AGES FORCE IN FN 2 AND APPENDS TO FN 2, N TIMES
[2]    I←1
[3]   L1:M←(0 ¯2 ↓M),12↑+/+/ 12 ¯2 ↑M← 12 21 ↑⎕FREAD 2,I ◇ CR←(W,W← 12 1 ρ(1-RA[;I])*0.5),CR
[4]    (MM,[1] A←M-MM←⌊0.5+CR×M←REC[;I],M) ⎕FAPPEND 2
[5]    →(N≥I←I+1)ρL1
[6]   ⍝ APPENDS STEADY STATE STOCKS TO FN 2
[7]    CR[;21]←12ρCR[1;21]÷1-CR[1;21] ◇ ((⍉ 21 12 ρREC[;I-1])××\CR) ⎕FAPPEND 2
    ∇
      ∇RECRUITS[⎕]∇
    ∇ M←RECRUITS V
[1]   ⍝ SPREADS RECRUITS OVER COHORTS
[2]    M←(4,NP)ρ0
[3]    M←M,[1](4,NP)ρ(Y3×W×1-WG),(Y3×NW×1-NWG),(Y3×W×WG),Y3×NW×NWG
[4]    M←M,[1](4,NP)ρ(Y4×W×1-WG),(Y4×NW×1-NWG),(Y4×W×WG),Y4×NW×NWG
[5]    M←M×(12,NP)ρV
    ∇
      ∇RATE[⎕]∇
    ∇ R←RATE N;A;S;CS;CF;I
[1]    I←0 ◇ S← 0 12 21 ρ0 ◇⍝READ IN STKS
[2]   L1:S←S,[1] A+0=A← 12 21 ↑⎕FREAD 1,BPI-I
[3]    →(N≥I←I+1)ρL1 ◇ CS← 0 0 19 ↓S ◇ CF←,CS[;1;2]
[4]    R←((12 18 ↑+/[1] ¯1 0 2 ↓S)÷(12 18 ↑+/[1] 1 0 1 ↓S)),12↑(+/¯1↓CF)÷(+/, 1 0 ¯1 ↓CS)++/1↓CF
    ∇
      ∇PRINTREPORT[⎕]∇
    ∇ PRINTREPORT;I;A;M;M1
[1]    2ρLF ◇ M1←⍉(8,1+NP)ρ(0,⍳NP),(100×(0,W,0,Y3,0,WG,0,NWG,0,HSA,0,LHSA)),0,T
[2]    '        USMC FORECASTED ENDSTRENGTHS         ',DATE ◇ 3ρLF
[3]    'BASE PERIOD: ';BP ◇ 'RATE METHOD: ';N ◇ 'HS FACTOR: ';HSF ◇ 'LHS FACTOR: ';LHSF ◇ I←0
[4]    LF
[5]    '    PERIOD    PERC W   PERC 3YR      W-HS      NW-HS      HS-RA    LHS-RA  RECRUITS   END STR TOTAL ATTR'
[6]   L1:,'BI10' ⎕FMT M1[1+I;],(+/+/ 12 21 ↑M),+/+/ ¯12 21 ↑M←⎕FREAD 2,I+1
[7]    →(NP≥I←I+1)ρL1 ◇ 'STDY. STATE',(69ρ' '),,'BI10' ⎕FMT+/+/⎕FREAD 2,I+1
    ∇
```